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Cooking oil fumes and risk of lung cancer in women in rural Gansu, China

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Abstract

Cooking oil fumes have been suggested to increase the risk of lung cancer in Chinese women by exposing them to mutagenic substances. We investigated the association between lung cancer and locally made rapeseed and linseed oils in a population-based case-control study in Gansu Province, China. Two hundred and thirty-three incident, female lung cancer cases diagnosed from 1994–98 were identified. A control group of 459 women was selected from census lists and were frequency matched on age and prefecture. Interviewers obtained information on cooking practices and cooking oil use. The odds ratio (OR) for lung cancer associated with ever-use of rapeseed oil, alone or in combination with linseed oil, was 1.67 (95% CI 1.0–2.5), compared to use of linseed oil alone. ORs for stir-frying with either linseed or rapeseed oil 15–29, 30 and ≥ 31 times per month were 1.96, 1.73, and 2.24, respectively (trend, $P = 0.03$), relative to a lower frequency of stir-frying. Lung cancer risks also increased with total number of years cooking (trend, $P < 0.09$). Women exposed to cooking fumes from rapeseed oil appeared to be at increased risk of lung cancer, and there was some evidence that fumes from linseed oil may have also contributed to the risk.

Keywords: Case-control studies; Cooking oil fumes; Lung neoplasms; Females; China

1. Introduction

Chinese women experience high incidence and mortality rates of lung cancer, especially adenocarcinoma [1,2]. Smoking may account for a relatively low percentage of the observed excess risk, since Chinese women tend not to smoke [3–6]. Indoor air pollutants such as environmental tobacco smoke (ETS) or combustion by-products from coal burning have been hypothesized to explain some of this excess lung cancer [4–15]. Fumes emitted from vegetable cooking oils during stir- and deep-frying are important contributors to indoor air pollution, particularly for women. Oils are usually first heated to high temperatures in a wok (large metal pan with raised sides) to reduce noxious odors, resulting in large emissions of fumes.

Several epidemiological studies have reported significant positive associations between lung cancer and exposure to cooking fumes [4–12,16–22]. Only two studies [4,21] have investigated lung cancer risk in relation to specific types of vegetable cooking oils, with risk estimates ranging from 1.4 to 1.8 for use of rapeseed oil, as compared to soybean oil. These findings were supported by laboratory studies [23–25]. Volatile organic compounds (e.g. 1,3 butadiene, benzene, acetaldehyde and acrolein) and formaldehyde were detected in cooking fumes, with higher levels in unrefined rapeseed oil and lower levels in soybean and peanut oils [25,26].

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Most investigations of lung cancer risk among Chinese women have been conducted in large cities where commercially produced oils are used, mainly rapeseed, soybean, and peanut oils. We report here on an analysis of lung cancer risk in women who participated in a population-based case-control study of lung cancer that was conducted in Gansu Province, a rural, non-industrial area of North-western China. The purpose of the analysis was to evaluate cooking fumes and cooking practices in relation to lung cancer. In this area, cooking oils are made locally in workshops and small factories with no or limited refining, using mechanical filtration and chemical purification, and from a variety of locally grown seeds including linseed, rapeseed, and to a lesser extent, perilla seed and hempseed.

2. Material and methods

2.1. Study subjects

Cases included female residents of Pingliang and Qingyang prefectures in Gansu Province, China, who were newly diagnosed with lung cancer between the ages of 30 and 75 years during the period January, 1994 through April, 1998. We ascertained cases retrospectively from January, 1994 to May, 1996, and prospectively from June, 1996 to April, 1998. Women with lung cancer were identified from local clinics, county and township hospitals, and county tuberculosis *anti*-epidemic stations. In addition, we identified residents of these two prefectures who were treated in public hospitals in nearby larger cities, Lanzhou, Xian, Baoji and Yinchuan City, and in one hospital affiliated with a petroleum oilfield company.

An expert panel of two oncologists, two radiologists, and one pathologist from the Gansu Province Department of Health, reviewed all available medical charts, X-ray or CT scan films, bronchoscopy reports, and cytologic/histologic reports or specimens of lung cancer. Based on their review, 238 cases of female lung cancer were identified. Among those, five (2%) were not located or moved out of the study area, leaving 233 (98%) cases. Sixty-three percent of diagnoses were based on clinical/radiological information, and 37% on cytologic or histologic evidence.

Female controls were randomly selected from 1990 population census lists of Pingliang and Qingyang prefectures. Controls were frequency matched by prefecture in 5-year age intervals, based on twice the expected numbers of cases determined from a review of medical records of lung cancer cases from 1991. Of 509 eligible female controls, 22 were not located (4%), five moved out the study area ($<1\%$), two refused to participate ($<1\%$), and 21 were not interviewed for various reasons (3%), leaving a total of 459 female (90%) controls available to participate in the study.

Cases and controls were interviewed at home or in the hospital by a trained interviewer, using a structured questionnaire. We collected information on a variety of cooking related variables, as well as data on socioeconomic and demographic factors, residential history over the past 30 years, tobacco use and exposure to environmental tobacco smoke, diet, and medical history. Next-of-kin, usually the spouse, completed the interview for 123 (53%) lung cancer cases and 20 (4%) controls. Retrospective cases or next-of-kin were interviewed within an average of 15 months after diagnosis, and 5 months for prospective cases.

2.2. Exposure assessment

Linseed and rapeseed oils were the principal types of oil used for cooking, with perilla and hempseed oils used only occasionally. For analysis, use of cooking oil was categorized as follows: (1) *Linseed oil alone*: ever-use of linseed oil and without use of rapeseed oil; (2) *Rapeseed oil alone*: ever-use of rapeseed oil and without use of linseed oil; (3) *Rapeseed and linseed oils*: ever-use of both rapeseed and linseed oils; and (4) *Perilla and hempseed oils*: ever-use of perilla and hempseed oils, and never use of linseed or rapeseed oils. These oil combinations were reported in 50, 18, 31, and 1% of the women in the study area, respectively. Women included in the first three categories may have occasionally cooked with perilla and hempseed oils. Most women cooked daily, using either coal or wood and sticks for fuel. When stir- or deep-frying, women initially heated the oil in a large, metal wok until fumes were emitted, which indicated that the cooking temperature was reached (about 220 °C fr stir-frying and 200–2l0 °C for deep-frying).

2.3. Statistical analysis

Logistic regression was performed to estimate the odds ratios (ORs) and to assess statistical significance, using the SAS program [27]. We adjusted all analyzes for the effects age at diagnosis for cases or age at interview for controls (<45, 45–54, 55–64, ≥ 65 years), prefecture, socioeconomic factors as represented by ownership of a color television (yes, no) and number of cattle per household (0, 1, ≥ 2), and self or next-of-kin respondent. Tests for trend were conducted using a score test.

3. Results

Table 1 shows the distribution of demographic characteristics of study subjects. Cases were more likely to have a higher level of income and education, own a color television, own fewer large animals, and live in

standard above ground dwellings and apartments. These factors were significantly associated with the types of cooking oil used. There were very few cases ($n = 27$) and controls ($n = 47$) who had ever smoked cigarettes or pipes for more than 6 months (Odds Ratio (OR) = 1.19, 95% confidence interval (CI) 0.7–2.0).

Odds ratios for lung cancer were elevated with use of rapeseed oil alone (OR = 1.65, 95% CI 0.8–3.2), and use of both rapeseed and linseed oils (OR = 1.70, 95% CI 1.0–2.8), compared to use of linseed oil alone (Table 2). For the remainder of the analyzes, we combined users of rapeseed oil alone and users of rapeseed and linseed oils. The OR for ever-use of rapeseed oil alone or in combination with linseed oil was 1.67 (95% CI 1.0–2.5) compared to use of linseed oil alone (data not shown). The number of subjects using perilla and hempseed oils only ($n = 10$) was sparse and they were excluded from further analyzes.

The risk of lung cancer increased significantly with frequency of stir-frying, with ORs for stir-frying 15–29, 30, and 31 times or more per month equal to 1.96, 1.73, and 2.24, respectively (test for trend, $P = 0.03$), compared to those who stir-fried less than 15 times a month (Table 3). The ORs for 30–39, 40–49 and 50 years or more of cooking were 1.26, 2.51, 2.46, although the trend did not reach the traditional level of statistical significance ($P < 0.09$). Only 19% of cases and 20% of controls deep-fried more than twice a month, and there was no pattern of increasing risk for this cooking method.

Table 1
Distribution of female lung cancer cases and controls by demographic characteristics, Gansu Province, China

Characteristics	Cases no. (%)	Controls no. (%)	Odds ratio and 95% confidence intervals[a]
Reference age			
<45	45 (19.3)	55 (12.0)	1.0
45–54	81 (34.8)	164 (35.7)	0.62 (0.4, 1.0)
55–64	74 (31.8)	152 (33.1)	0.60 (0.4, 1.0)
≥65	33 (14.2)	88 (19.2)	0.48 (0.3, 0.9)
Prefecture			
Pingliang	116 (49.8)	264 (57.5)	1.0
Qingyang	117 (50.2)	195 (42.5)	1.22 (0.9, 1.7)
Annual income			
<2000	53 (22.7)	111 (24.6)	1.0
2000–3999	81 (34.8)	175 (38.8)	1.12 (0.7–1.7)
>4000	99 (42.5)	165 (36.6)	1.11 (0.7–1.7)
Education			
Primary or less	201 (86.3)	438 (95.4)	1.0
Technical/vocation	20 (8.58)	14 (3.05)	1.91 (0.9–4.0)
College and above	12 (5.15)	7 (1.52)	1.71 (0.6–4.7)
Number of persons in household			
1–3	39 (16.8)	63 (13.7)	1.0
4–6	90 (38.8)	174 (38.0)	0.92 (0.6–1.5)
≥6	103 (44.4)	221 (48.2)	1.11 (0.7–1.9)
TV-color			
No	157 (67.4)	373 (81.6)	1.0
Yes	76 (32.6)	84 (18.4)	1.72 (1.2–2.5)
Number of cattle			
0	126 (54.1)	156 (34.0)	1.0
1	55 (23.6)	151 (32.9)	0.53 (0.4–0.8)
≥2	52 (22.3)	152 (33.1)	0.50 (0.3–0.8)
Type of current dwelling			
Underground[b]	74 (31.8)	177 (38.6)	1.0
Standard	159 (68.2)	282 (61.4)	1.46 (1.0–2.2)
Smoke cigarettes			
No	206 (88.4)	411 (89.7)	1.0
Yes	27 (11.6)	47 (10.3)	1.19 (0.7–2.0)
Total[c]	233	459	

[a] Odds ratios are adjusted for age, prefecture and socioeconomic factors, as represented by ownership of a color television and number of cattle.
[b] Underground dwelling includes all cave-like housing styles. Standard dwelling includes the standard above ground style and apartment.
[c] Actual numbers differ slightly for each household characteristic due to missing data.

Table 2
Odds ratios for lung cancer by type of vegetable cooking oil

Type of oil	Cases	Controls	OR[a]	95% CI
Linseed oil[b]	80	247	1.0	
Rapeseed oil[c]	58	79	1.65	(0.8–3.2)
Rapeseed and linseed oils[d]	90	126	1.70	(1.0–2.8)
Perilla and hempseed oils[e]	5	5	3.25	(0.8–14.0)
Total	233	457		

[a] Odds ratios are adjusted for age, prefecture, socioeconomic factors, as represented by ownership of a color television and number of cattle, type of respondent.
[b] Includes ever-use of linseed oil and no rapeseed oil. Use of perilla oil and hempseed oil was occasional.
[c] Includes ever-use of rapeseed oil and no linseed oil. Use of perilla oil and hempseed oil was occasional.
[d] Includes ever-use of both rapeseed and linseed oils. Use of perilla oil and hempseed oil was occasional.
[e] Includes ever-use of perilla oil and hempseed oil and no use of rapeseed and linseed oils.

Risk of lung cancer increased significantly with the degree of eye and throat irritation while cooking (test for trend, $P < 0.01$), with OR = 1.37 for women who reported suffering irritation 'sometimes/seldom', and OR = 2.82 for those with 'frequent' irritation (Table 4). The general level of indoor smokiness, however, was not associated with lung cancer.

4. Discussion

Our results suggested that women who ever-cooked with rapeseed oil, alone or in combination with linseed oil, experienced a statistically significant 67% increased risk of lung cancer compared to those who used linseed oil alone. We also observed a significant dose–response of increased risk with increased frequency of stir-frying among women who ever-cooked with either rapeseed or linseed oil. Risk also increased with total number of years cooking with either oil. We found an association between lung cancer and self-reported degree of eye and throat irritation, but not the general level of home smokiness.

Studies conducted in Shanghai, which compared use of rapeseed oil to soybean oil, have reported associations of similar magnitude [4,21]. Positive associations between lung cancer and stir- and deep-frying have been described in Chinese women from Shenyang and Harbin [5,7,10,11] who cook primarily with soybean oil, and from Taiwan [19,20] where peanut and soybean oils are predominant. However, none of these oils were regularly used in our study population. In our study, in addition to rapeseed oil, we observed increasing risks of lung cancer with frequency of stir-frying and years of cooking with linseed oil, suggesting that exposure to fumes from linseed oil may also carry a risk of lung cancer.

Our results for stir-frying were similar to other studies [4,19–21], whereas our results for deep-frying with either oil were not. Approximately 1.5–2-fold increased risks have been reported for frequent deep-frying in areas where rapeseed, soybean, and peanut oils are used [4,5,19–21]. We measured the temperature of oil for deep-frying in local households, and found it relatively low (200–210 °C), compared to typical cooking temperatures reported in Shanghai (270–280 °C) [21,23]. The absence of a demonstrable risk from deep-frying in our study may thus be due to the lower temperature, resulting in less fumes emitted or mutagenic substances produced. Additionally, deep-frying was relatively uncommon in our study area with few women deep-frying more than twice a month.

Conflicting findings have been reported for duration of cooking [8,12,18] while young age at started cooking was consistently found to increase the risk of lung cancer [8,19,20]. In our study, there was no clear effect on lung cancer risk of age started cooking. Risk of lung cancer did show a suggestive increase with years of cooking, but not with the amount of oil used per month.

In our study, eye/throat irritation was related to increased risk, confirming previous findings [4,5,21]. We found no relationship with the general level of home smokiness, in contrast to other studies [4,6,7,10,17,21]. Our sub-study of indoor air pollutants in underground cave dwellings in Gansu Province reported high ventilation rates as measured by air exchanges per hour [28]. These high ventilation rates may explain our findings for lack of any risk associated with general smokiness. In a study by Zhong et al. [21] lung cancer risk decreased with increasing total area of windows in the apartment, used as a surrogate measure for ventilation.

Several laboratory studies have demonstrated the presence of mutagenic substances in condensates [23–25] and vapors [29–31] from Chinese vegetable oils. Unrefined and refined Chinese rapeseed oils heated at high temperature were highly mutagenic in experimental settings that was hypothesized to be related to linolenic acid content [23,25]. High levels of volatile organic compounds (e.g. 1,3 butadiene, benzene, and acrolein) and formaldehyde have been detected in emissions from unrefined rapeseed oil [25,26]. Polycyclic aromatic hydrocarbons (PAHs) such as dibenzo(a,h)anthracene were also present in cooking oil fumes obtained in experimental settings and in air samples from kitchens [32–34]. However, a variety of sources of PAHs such as home heating fuel, cooking fuel, and tobacco smoking may have contributed to those findings. In the Gansu pilot study of indoor air pollutants [28], high levels of PAHs were detected when cooking stoves and heating kangs were in use.

The study has potential limitations. Although linseed and rapeseed oils were the most frequently used oils in the study area, women who cooked with either oil occasionally used perilla oil or hempseed as well. Thus, it was not possible to investigate fully the independent effect of use of rapeseed or linseed oils without perilla oil. The possibility of non-differential missclassification of exposure may have limited our ability to detect an effect of rapeseed and linseed oil. Our data lacked a 'low-risk' oil for a referent group, since use of linseed oil appears to increase the risk of lung cancer. Therefore, the magnitude of the association with use of rapeseed oil may be underestimated relative to a 'low risk' oil.

We included next-of-kin respondents in the analysis, and we found that results were very similar when data were limited to self-interviewed subjects or adjusted for respondent type. In addition, smokers were retained in analyzes, since few women smoked and the OR for ever-smokers compared to never-smokers was 1.19. We relied on clinical/radiological information for the diagnosis of lung cancer when pathological evidence was not available. The results from analyzes restricted to histologically confirmed cases were generally similar to those reported for all lung cancer cases. Additional adjustment for exposure to active smoking, environmental tobacco smoke, residential radon, heating fuel and type of dwelling did not affect the risk estimates.

5. Conclusion

In summary, we found that women who stir-fried frequently, especially with rapeseed oil, had an increased risk of lung cancer. In addition, risk for lung cancer increased with total number of years spent cooking. There was also evidence that exposure to cooking fumes from linseed oil may have also contributed to this risk. Reports of eye/throat irritation associated with use of these oils also conferred a significantly increased risk of lung cancer in women.

Table 3
Odds ratios for lung cancer for cooking practices by use of linseed oil alone and rapeseed oil alone or in combination with linseed oil

Factors	Linseed oil[a]			Rapeseed oil[b]			Total	
	Cases/controls	OR[c]	95% CI	Cases/controls	OR[c]	95% CI	OR[d]	95% CI
Stir-frying (*times per month*)								
Less than 15	26/105	1.00		45/91	1.00		1.00	
15–29	19/56	1.25	0.5–2.9	41/37	2.73	1.3–5.8	1.96	1.1–3.5
30	22/65	1.19	0.5–2.7	30/45	2.29	1.0–5.0	1.73	1.0–3.1
31 or more	13/21	2.16	0.8–6.0	32/32	2.37	1.0–5.7	2.24[e]	1.1–4.5
Deep-frying (*times per month*)								
Never/less than once	10/111	1.00		60/85	1.00		1.00	
1–2	29/82	0.71	0.3–1.4	57/75	0.91	0.5–1.7	0.82	0.5–1.3
3 or more	10/27	1.03	0.4–2.8	28/41	0.75	0.4–1.6	0.83	0.5–1.5
Amount of oil (*catty*[f] *per month*)								
3 or less	46/151	1.00		66/92	1.00		1.00	
4–5	21/70	1.20	0.6–2.5	55/80	0.77	0.4–1.4	0.93	0.6–1.5
6 or more	13/26	1.50	0.6–3.8	27/33	1.03	0.5–2.2	1.22	0.7–2.2
Numbers of meals cooked (*per day*)								
2 or less	77/218	1.00		116/174	1.00		1.00	
3 or more	6/26	0.59	0.2–1.9	30/31	1.87	1.0–3.7	1.36	0.8–2.4
Age start cooking								
13 or less	21/68	1.00		42/54	1.00		1.00	
14–16	35/88	1.51	0.7–3.4	50/91	0.39	0.2–0.8	0.69	0.4–1.1
17 or more	24/91	0.76	0.3–1.8	56/60	0.66	0.3–1.3	0.69	0.4–1.2
Years of cooking								
29 or less	21/40	1.00		31/41	1.00		1.00	
30–39	24/86	1.02	0.3–3.1	52/68	1.44	0.6–3.6	1.26	0.6–2.8
40–49	23/69	2.59	0.7–9.2	42/63	2.49	0.8–7.6	2.51	0.9–6.8
50 or more	9/46	2.27	0.5–10.5	20/33	2.65	0.7–9.3	2.46	0.8–7.9

[a] Includes women who ever used linseed oil and no rapeseed. Use of perilla oil and hempseed oil was occasional.
[b] Includes women who ever used rapeseed oil alone or in combination with linseed oil. Use of perilla oil and hempseed oil was occasional.
[c] Odds ratios are adjusted for age, prefecture, socioeconomic factors, and type of respondent.
[d] Odds ratios are adjusted for age, prefecture, socioeconomic factors, type of respondent and type of cooking oil.
[e] Test of trend, $P<0.05$.
[f] One catty equals 0.5 l.

Table 4
Odds ratios for lung cancer for measures of exposure to cooking fumes by use of linseed and rapeseed oils

Factors	Linseed oil[a]			Rapeseed oil[b]			Total	
	Cases/controls	OR[c]	95% CI	Cases/controls	OR[c]	95% CI	95% CI[d]	
Eye-throat irritation								
Never	28/118	1.00		44/64	1.00		1.00	
Sometimes/seldom	32/86	2.05	1.0–4.3	68/111	1.04	0.5–2.0	1.37	0.8–2.2
Frequently	19/42	2.55[e]	1.1–6.0	35/29	3.00[f]	1.4–6.5	2.82[f]	1.6–5.0
Home smokiness								
No	25/77	1.00		24/41	1.00		1.00	
Some/little	46/138	0.69	0.3–1.4	109/130	1.15	0.6–2.3	0.90	0.6–1.5
Considerable	9/32	0.92	0.3–2.6	14/31	0.72	0.3–2.0	0.76	0.4–1.6

[a] Includes women who ever used linseed oil and no rapeseed. Use of perilla oil and hempseed oil was occasional.
[b] Includes women who ever used rapeseed oil alone or in combination with linseed oil. Use of perilla oil and hempseed oil was occasional.
[c] Odds ratios are adjusted for age, prefecture, socioeconomic factors, and type of respondent.
[d] Odds ratios are adjusted for age, prefecture, socioeconomic factors, type of respondent and type of cooking oil.
[e] Test of trend, $P<0.05$.
[f] Test of trend, $P<0.01$.

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